

NASA-TM-103776

# PM200 PS200

Self-Lubricating Bearing  
and Seal Materials for  
Applications to 900 °C

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(NASA-TM-103776) PM200/PS200:  
SELF-LUBRICATING BEARING AND SEAL MATERIALS  
FOR APPLICATIONS TO 900 C (NASA) 17 P

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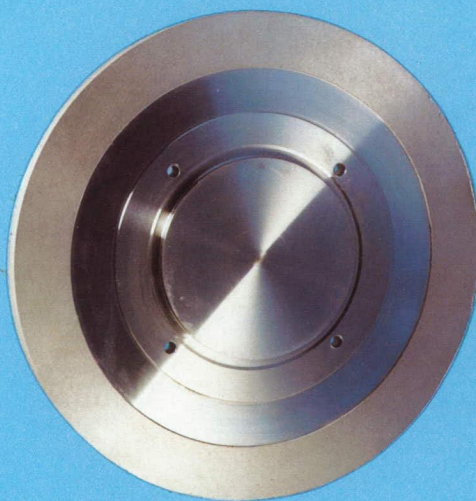
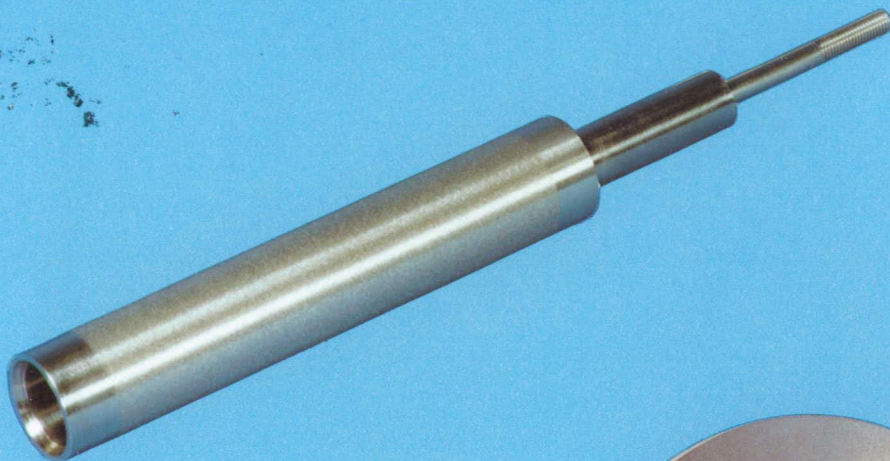
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NASA Lewis Research Center  
Cleveland, Ohio



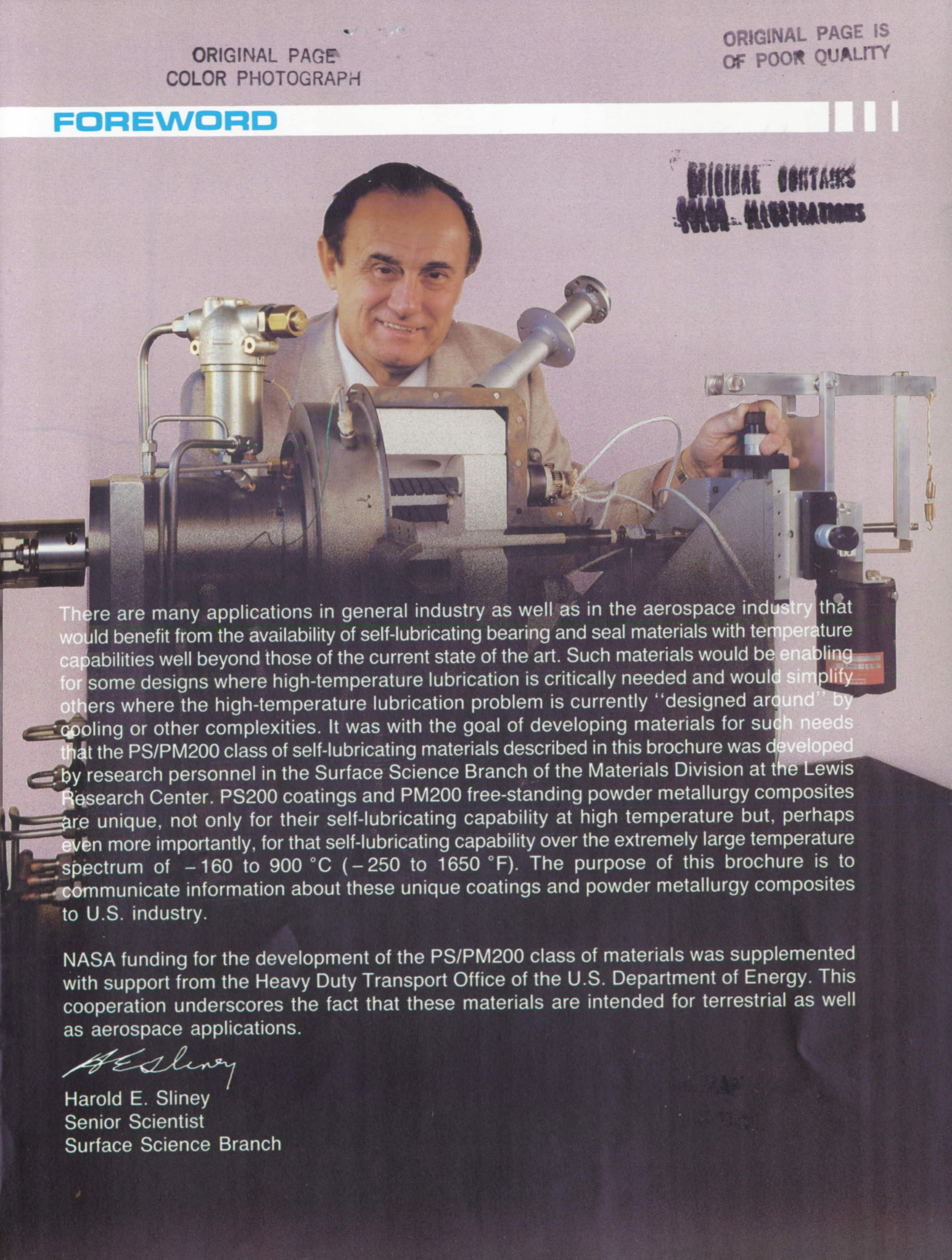


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## FOREWORD

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There are many applications in general industry as well as in the aerospace industry that would benefit from the availability of self-lubricating bearing and seal materials with temperature capabilities well beyond those of the current state of the art. Such materials would be enabling for some designs where high-temperature lubrication is critically needed and would simplify others where the high-temperature lubrication problem is currently "designed around" by cooling or other complexities. It was with the goal of developing materials for such needs that the PS/PM200 class of self-lubricating materials described in this brochure was developed by research personnel in the Surface Science Branch of the Materials Division at the Lewis Research Center. PS200 coatings and PM200 free-standing powder metallurgy composites are unique, not only for their self-lubricating capability at high temperature but, perhaps even more importantly, for that self-lubricating capability over the extremely large temperature spectrum of  $-160$  to  $900^{\circ}\text{C}$  ( $-250$  to  $1650^{\circ}\text{F}$ ). The purpose of this brochure is to communicate information about these unique coatings and powder metallurgy composites to U.S. industry.

NASA funding for the development of the PS/PM200 class of materials was supplemented with support from the Heavy Duty Transport Office of the U.S. Department of Energy. This cooperation underscores the fact that these materials are intended for terrestrial as well as aerospace applications.



Harold E. Sliney  
Senior Scientist  
Surface Science Branch



Bearing and seal materials are needed that are self-lubricating at very high temperatures. Such materials must have lubricating capabilities well beyond those of the present oils, greases, and conventional solid lubricants.

## RELEVANT APPLICATION AREAS

- **Manufacturing**
  - Glass-forming equipment bearings
  - Metal-working equipment bearings
- **Reciprocating Engines**
  - Cylinder liner coatings
  - Valve guides and seats
- **Rotary Engines**
  - Apex seals
  - Combustion chamber coating
- **Gas Turbine Engines**
  - Shaft seals
  - Variable stator vane bushings
  - Variable geometry gas path mechanisms
- **Auxiliary Turbomachinery**
  - Gas bearings
    - Backup lubricant for start-stop and high-speed runs
- **Super- and Hypersonics**
  - Control surface bearings and seals
  - Airframe thermal expansion joints

The PS/PM200 system is a series of self-lubricating composites with a duplex microstructure consisting of a hard carbide phase with soft noble metal and stable fluoride phases.

PS200 composites are plasma-sprayed coatings, and PM200 composites are free-standing sintered or hot isostatically pressed (HIPed) Powder Metallurgy parts.

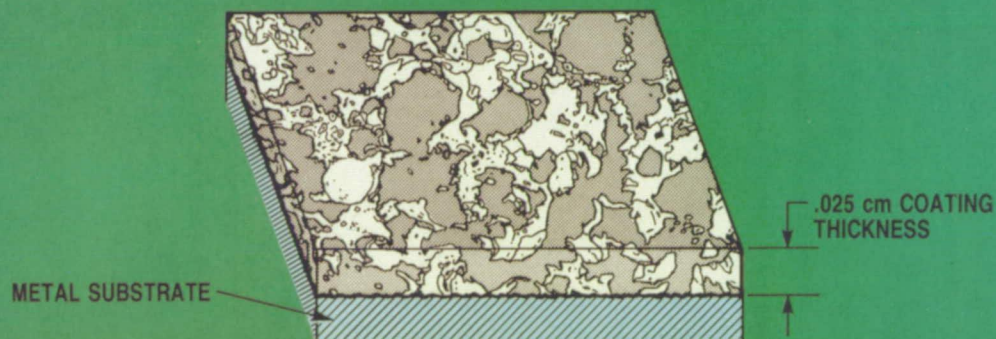
The ratio of carbide to soft phases can be tailored depending on design requirements such as conformability and hardness.

Typical preferred weight ratios of nickel-alloy-bonded chromium carbide to silver to barium fluoride/calcium fluoride eutectic are as follows:

PS200: 80-10-10

PS212 and PM212: 70-15-15

## The Concept



### COMPOSITION

32% Ni ALLOY —  
48%  $\text{Cr}_3\text{C}_2$

10% Ag

10%  $\text{BaF}_2/\text{CaF}_2$  —  
EUTECTIC

### CHARACTERISTICS

WEAR AND OXIDATION RESISTANT METAL BONDED CARBIDE

LOW TEMPERATURE START UP LUBRICANT WITH HIGH  
TEMPERATURE OXIDATION RESISTANCE

HIGH TEMPERATURE LUBRICANT

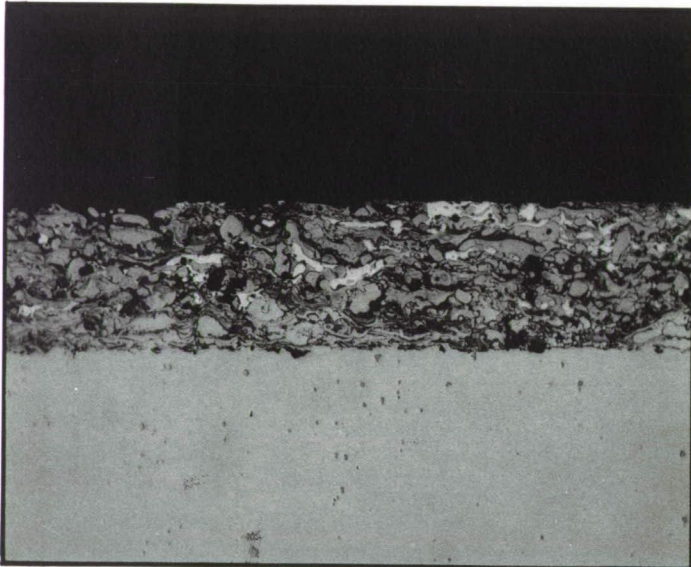
• LUBRICATES IN AIR, HELIUM, OR HYDROGEN TO +900 °C

CD-86-18683

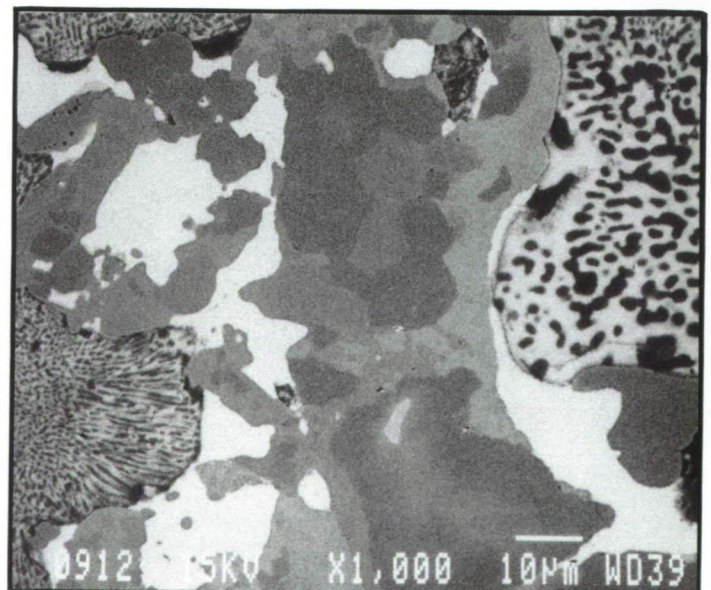
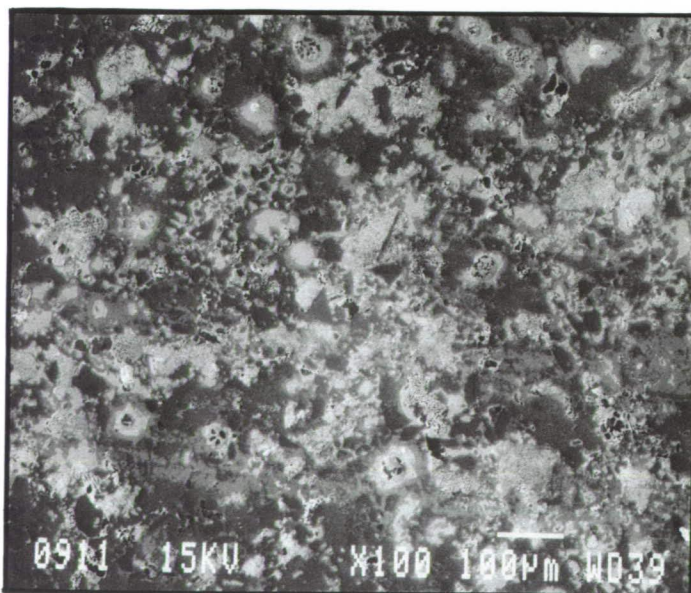


## 4 MICROSTRUCTURE

These materials consist of a matrix of metal bonded chromium carbide containing dispersed silver and a eutectic of calcium fluoride and barium fluoride. The microstructure of plasma-sprayed PS212 is stratified by the application method—multiple passes with a spray torch. The powder metallurgy versions contain randomly dispersed solid lubricants.

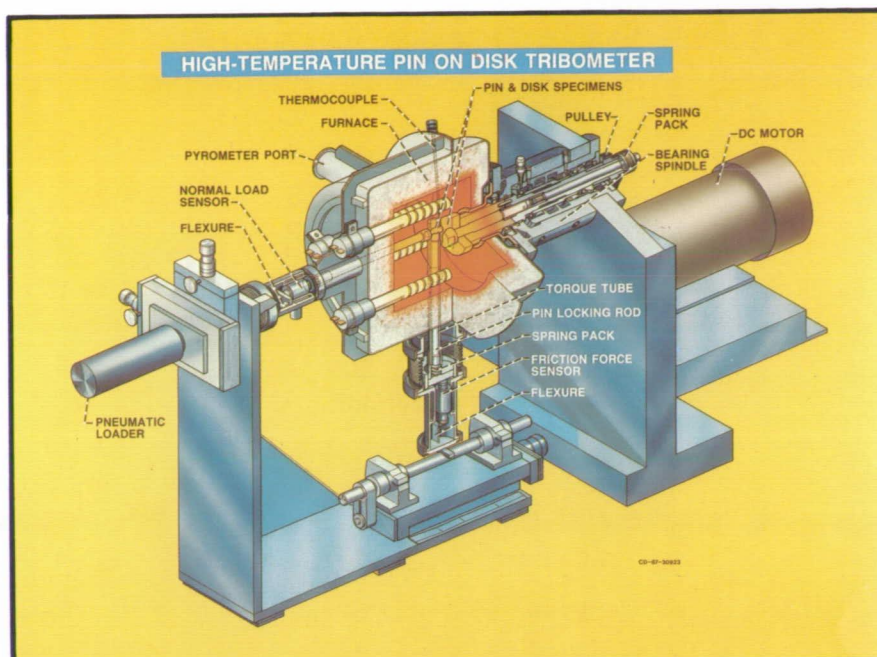


Plasma-sprayed PS212

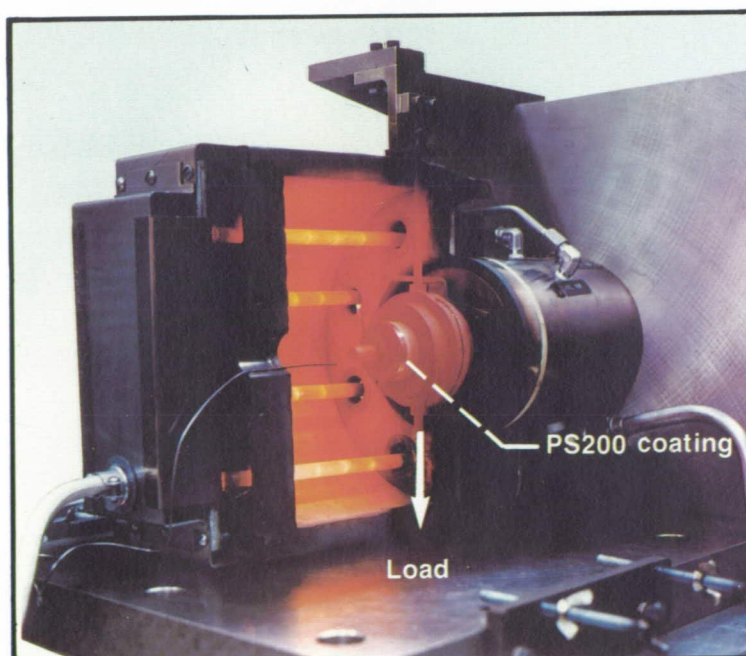


Hot isostatically pressed PM212



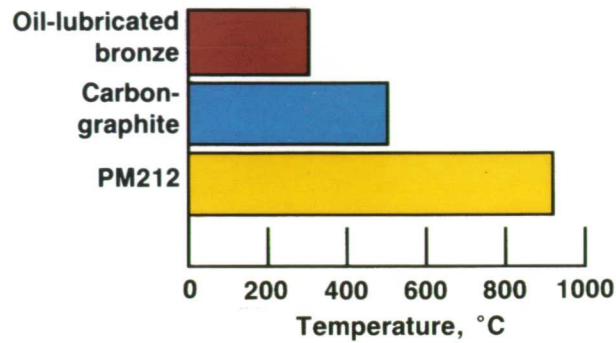


Basic friction and wear properties were measured in atmospheres of air, hydrogen, and helium over a wide range of temperatures and sliding velocities.

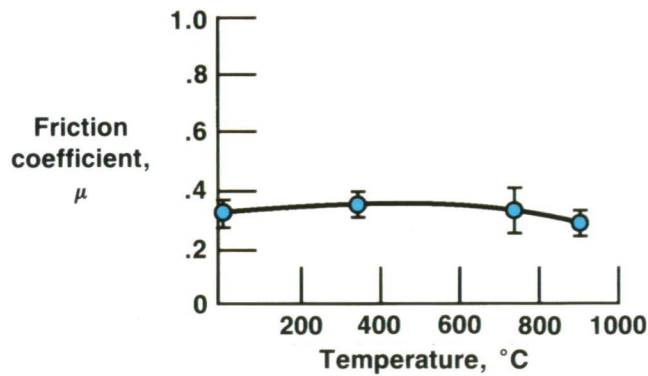


Further evaluation was performed with actual mechanical components such as the PS200-lubricated journal bearing shown under test in this photograph. (One side of the furnace was briefly removed to expose the bearing for this illustration.)

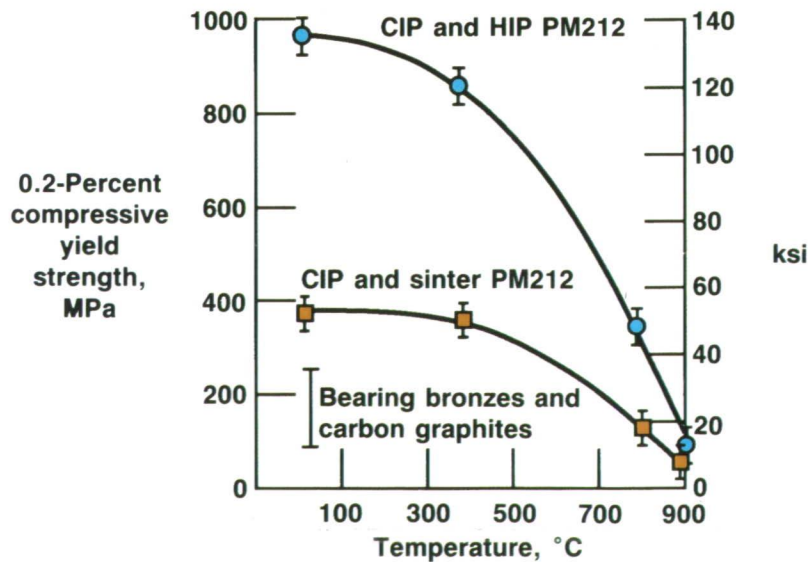
## SUPERIOR MAXIMUM SERVICE TEMPERATURE



## NONGALLING AND MODERATE FRICTION TO 900 °C



## MECHANICAL STRENGTH COMPARES FAVORABLY WITH CONVENTIONAL SLIDING BEARING MATERIALS





## LINEAR THERMAL EXPANSION

| Material                                     | Temperature range, °C | Thermal expansion coefficient, °C <sup>-1</sup> |
|--|-----------------------|---|
| PM212  | 25 to 550             | 12.2e <sup>-6</sup>                             |
|  | 25 to 850             | 14.2  |
| Bonded Cr <sub>2</sub> C <sub>3</sub> matrix | 25 to 550             | 12.2  |
|  | 25 to 850             | 13.3  |
| Ag   | 25 to 900             | <sup>a</sup> 28.4                               |
| CaF <sub>2</sub>                             | 25 to 627             | <sup>a</sup> 36.6                               |
| BaF <sub>2</sub>                             | 25 to 577             | <sup>a</sup> 25.8                               |
| Cr <sub>3</sub> C <sub>2</sub>               | 25 to 927             | <sup>a</sup> 12.1                               |
| Ni   | 25 to 927             | <sup>a</sup> 18.3                               |

<sup>a</sup>Touloukian, Y.S., et al., Thermophysical Properties of Matter. Vol. 12 Plenum, 1975.

## THERMAL CONDUCTIVITY PARAMETERS

| Composite      | Temperature |        | Density, gm/cm <sup>3</sup> | Specific heat, W·sec/gm·K | Diffusivity, cm <sup>2</sup> /sec | Conductivity |                                |
|----------------|-------------|--------|-----------------------------|---------------------------|-----------------------------------|--------------|--------------------------------|
|                | °C          | °F     |                             |                           |                                   | W/cm·K       | Btu·in./hr·ft <sup>2</sup> ·°F |
| Sintered PM212 | 23.0        | 73.4   | 5.141                       | 0.4780                    | 0.04050                           | 0.09952      | 69.01                          |
|                | 100.0       | 212.0  |                             | .5150                     | .04030                            | .10670       | 73.98                          |
|                | 200.0       | 392.0  |                             | .5410                     | .04070                            | .11320       | 78.49                          |
|                | 300.0       | 572.0  |                             | .5570                     | .04140                            | .11855       | 82.20                          |
|                | 400.0       | 752.0  |                             | .5750                     | .04300                            | .12711       | 88.13                          |
|                | 500.0       | 932.0  |                             | .6020                     | .04350                            | .13463       | 93.34                          |
|                | 600.0       | 1112.0 |                             | .5280                     | .04560                            | .14722       | 102.08                         |
|                | 700.0       | 1292.0 |                             | .6570                     | .04670                            | .15774       | 109.37                         |
|                | 800.0       | 1472.0 |                             | .6950                     | .04670                            | .16686       | 115.69                         |
|                | 900.0       | 1652.0 |                             | .7480                     | .04430                            | .17035       | 118.11                         |
| HIPed PM212    | 23.0        | 73.4   | 6.566                       | 0.4870                    | 0.04240                           | 0.13558      | 94.00                          |
|                | 100.0       | 212.0  |                             | .5270                     | .04240                            | .14672       | 101.73                         |
|                | 200.0       | 392.0  |                             | .5570                     | .04310                            | .15763       | 109.29                         |
|                | 300.0       | 572.0  |                             | .5730                     | .04470                            | .16818       | 116.60                         |
|                | 400.0       | 752.0  |                             | .5870                     | .04670                            | .17999       | 124.80                         |
|                | 500.0       | 932.0  |                             | .6130                     | .04830                            | .19441       | 134.79                         |
|                | 600.0       | 1112.0 |                             | .6490                     | .04930                            | .21008       | 145.66                         |
|                | 700.0       | 1292.0 |                             | .6820                     | .05050                            | .22614       | 156.79                         |
|                | 800.0       | 1472.0 |                             | .7190                     | .05120                            | .24171       | 167.59                         |
|                | 900.0       | 1652.0 |                             | .7600                     | .04860                            | .24252       | 168.15                         |

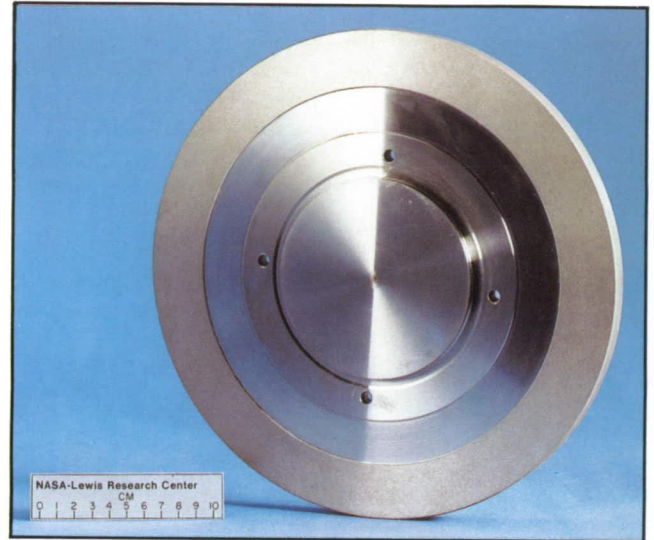


## Coatings

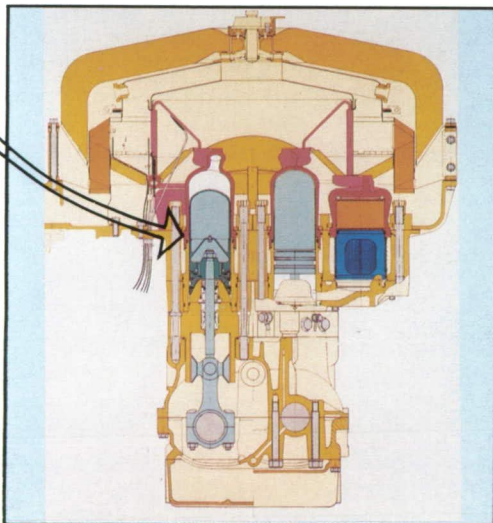
Coatings are suitable for areas readily accessible for nearly perpendicular spraying. Some examples of PS200-coated components are illustrated.



Stirling engine cylinder  
after 22-hour engine test



High-speed shaft seal



Automotive Stirling engine



Gas bearing journal

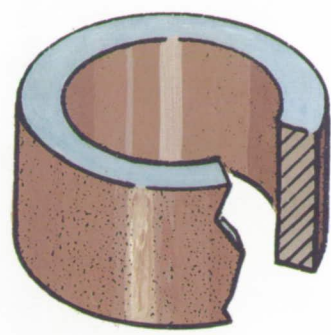
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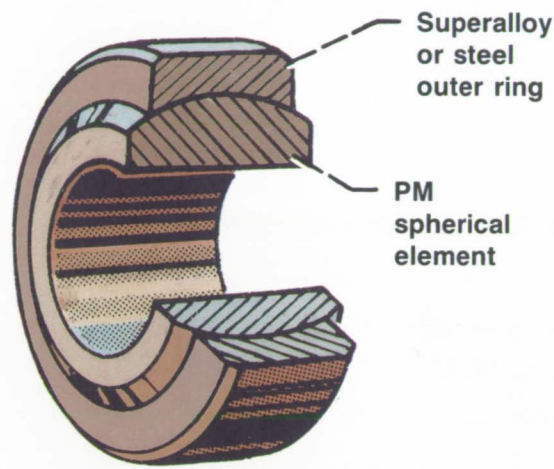


Powder Metallurgy Parts

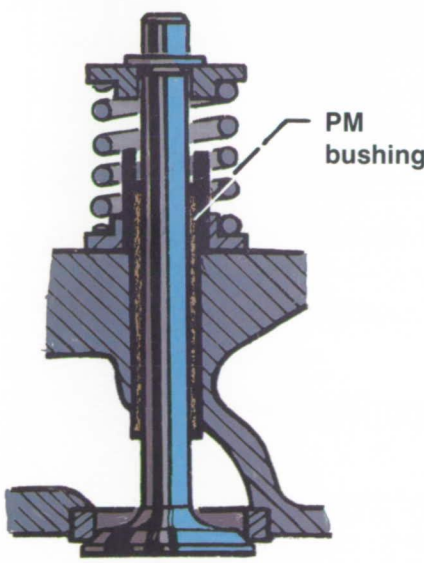
Powder metallurgy (PM) parts are ideal for small bore cylindrical bearings, valve stem guides, variable stator vane bushings for gas turbine machinery, plain spherical bearings, and combustion chamber liners for small engines.



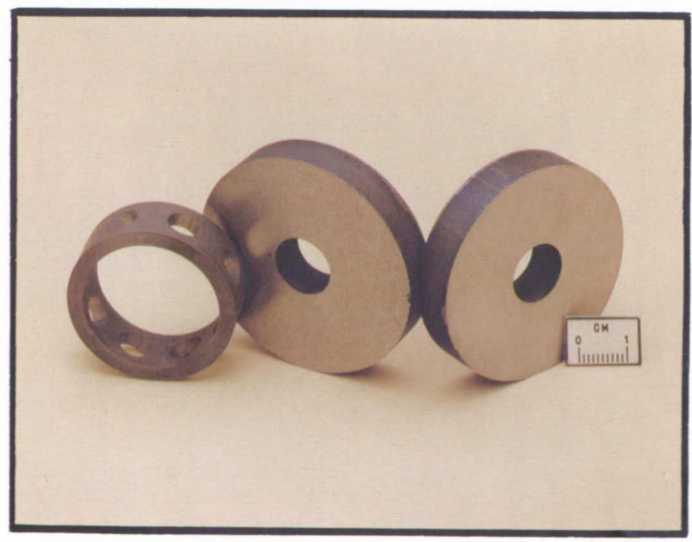
PM bushing



Control surface bearing



Valve application



HIPed bearing cage and wear test specimens

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# 10 POTENTIAL AEROSPACE APPLICATIONS

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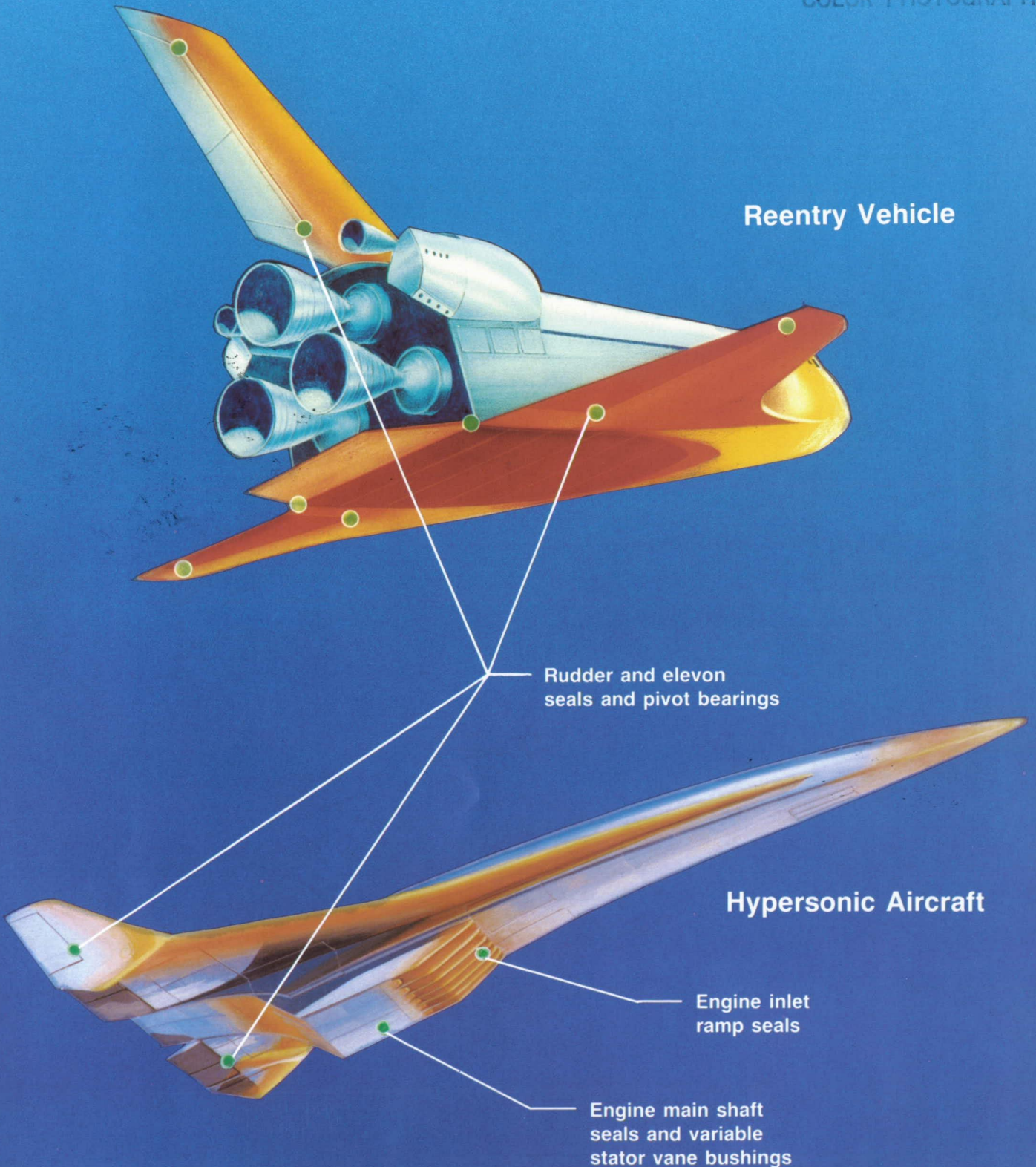
Reentry Vehicle

Rudder and elevon  
seals and pivot bearings

Hypersonic Aircraft

Engine inlet  
ramp seals

Engine main shaft  
seals and variable  
stator vane bushings





The concept of carbide/fluoride/silver self-lubricating composites and the general preparation methods with emphasis on plasma spraying are described in—

U.S. Patent 4,728,488: *Carbide/Fluoride/Silver Self-Lubricating Composites.*

Issued: March 1, 1988

Inventor: Harold E. Sliney

Assignee: U.S. Government, NASA

Method for making free-standing carbide/fluoride/silver parts by metallurgy processes is described in—

U.S. Patent 5,034,187: *Method of Making Carbide/Fluoride/Silver Composites.*

Issued: July 23, 1991

Inventors: Harold E. Sliney and Christopher DellaCorte

Assignee: U.S. Government, NASA

Licensing is available. For details contact:

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DellaCorte, C.; and Sliney, H.E.: Composition Optimization of Self-Lubricating Chromium Carbide-Based Composite Coatings for Use to 760 °C. ASLE Trans., vol. 30, no. 1, Jan. 1987, pp. 77–83.

DellaCorte C.; and Sliney, H.E.: Tribological Properties of PM212: A High Temperature, Self-Lubricating, Powder Metallurgy Composite. Lubr. Eng., vol. 47, no. 4, Apr. 1991.

Edwards, P.M.; et al.: Mechanical Strength and Thermophysical Properties of PM212: A High Temperature, Self-Lubricating Powder Metallurgy Composite. NASA TM-103694, DOE/NASA/50162-5, 1990.

Sliney, H.E.: A New Chromium Carbide-Based Tribological Coating for Use at 900 °C with Particular Reference to the Stirling Engine. J. Vac. Sci. Technol. A, vol. 4, no. 6, Nov./Dec. 1986, pp. 2629–2632.

Sliney, H.E.: Coatings for High Temperature Bearings and Seals. NASA TM-100249, DOE/NASA/50112-71, 1987.

Sliney, H.E.: Some Composite Bearing and Seal Materials for Gas Turbine Applications—A Review. J. Eng. Gas Turbines Power, vol. 112, no. 4, Oct. 1990, pp. 486–491.

Sliney, H.E.: Composite Bearing and Seal Materials for Advanced Heat Engine Applications to 900 °C. NASA TM-103612, DOE/NASA 50162-4, 1990.

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| 7. Author(s)<br>Harold E. Sliney  |  |  |  | 8. Performing Organization Report No.<br>E-6043                               |  |
|   |  |  |  | 10. Work Unit No.<br>505-63-5A  |  |
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|   |  |  |  |   |  |
| 15. Supplementary Notes<br>Responsible person, Harold E. Sliney, (216) 433-6055.  |  |  |  |   |  |
| 16. Abstract<br><br>This brochure is intended to inform both the technical and nontechnical reader of a new class of wear-resistant composite materials that can be prepared as coatings by the plasma spray process or as free-standing bearings by powder metallurgy processing. These new materials can be used over an exceptionally large temperature range from -100 to 900 °C. They are corrosion resistant at high temperatures in strong reducing atmospheres such as hydrogen and in oxidizing atmospheres such as air. The coating (PS200) and free-standing (PM200) variations are complimentary in their applicability. The PM composites can be readily fabricated into parts that cannot be readily plasma sprayed such as bushings and cylinders with small bore diameters and/or large length to diameter ratios. Suggested applications for PS200 coatings and PM200 parts are described. |  |  |  |   |  |
| 17. Key Words (Suggested by Author(s))<br>Solid lubricants; High temperature lubricants; Sprayed coatings; Plasma spraying; Powder metallurgy; Bearings; Self-lubricating materials; Self-lubrication; Metal matrix composites; Composite materials   |  |  |  | 18. Distribution Statement<br>Unclassified - Unlimited<br>Subject Category 24 |  |
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|   |  |  |  | 22. Price*<br>A03   |  |



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Mr. Harold E. Sliney or Dr. Christopher DellaCorte  
NASA Lewis Research Center  
Mail Stop 23-2  
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